OHIO DRAINAGE CONTRACTOR CHARACTERISTICS AND INSTALLATION PRACTICES

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ABSTRACT

Improved subsurface drainage continues to be a priority for agricultural producers in Ohio. Much of the subsurface drain pipe is installed by specialty drainage contractors. Little research has been reported concerning the design practices and characteristics of subsurface drain installers. To develop background information for the Ohio Agricultural Water Management Guide, a mail survey was conducted to inventory contractor practices and estimate the extent of subsurface drainage installation from 1995-1997.

Respondents were classified into two categories: those which installed subsurface drainage as their main business, and those for which it is a sideline business. Over 90% of the mainline firms had been in business for 11 years or more. Respondents reported the installation of over 10 000 km of drain pipe in 1997. Relatively few controlled drainage and sub-irrigation system installations were reported. Mainline firms installed about 90% of the total drain pipe installed. These firms rely on experience and self-generated topographic maps as their primary design aids. Many contractors reported the same drain depth and spacing for different soil series, suggesting that the soil type is not a main consideration in the installation. Further education and training may be needed to improve the design practices used by Ohio drainage contractors

KEYWORDS. Agricultural drainage, drainage contractors, drain installation practices, drain spacing, drain depth.

INTRODUCTION

Drainage contractors are one of the key audiences of the proposed Ohio Agricultural Water Management Guide and its predecessors the Ohio Drainage Guide (USDA, 1973) and the Ohio Irrigation Guide. In their discussion of drainage design practices at the Fifth National Drainage Symposium, Nolte et al. (1987) state that the majority of on-farm drainage systems are designed by contractors. They also indicate that the producer's wishes are often the deciding factor in most design decisions, and that tradition has a great influence on system design. Skaggs (1987) also notes that most drainage systems are not designed using any objective method for tailoring the systems to particular soil properties and crop needs, in spite of decades of research in drainage design.

Nolte et al. (1987) discuss the role of drainage guides in drainage system design. The drainage guide serves as a general reference to drainage design, often containing a general description of the area for which they are written, the extent of drainage problems, a discussion of drainage

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methods, and a list of soil associations with accompanying drainage guidelines. They feel the drainage guide should be especially useful to drainage contractors and planners, but state that the guide is not intended to be the sole reference for system design.

Little data exists in the literature regarding drainage contractors, their practices, and their need for a drainage or water management guide. In the only related study found by the author, Buriak et al. (1993) used a Delphi process to identify 89 technical and 41 business/professional competencies needed by a successful land improvement contractor. No other examples of studies relating to drainage contractors were found.

To support efforts to develop a useful Ohio Agricultural Water Management guide, a mail survey of Ohio drainage contractors was envisioned to provide information relating to the practices of drainage contractors. This study had three objectives:

1. Profile subsurface drainage contractors doing work in Ohio;
2. Assess subsurface drainage, controlled drainage, and subirrigation installation activity in Ohio;
3. Compare subsurface drain installation depth and spacing used by Ohio contractors with the results of the Hooghoudt equation.

The results of this survey are presented in this paper. We will first review the methods used to conduct the study, then discuss contractor characteristics, the tools used to design drainage systems, educational topics of interest, the amount of subsurface drain pipe installed, and finally, the drain depth and spacing values reported by contractors for the installation of drain pipe in several common soil series in Ohio.

METHODS

To meet the objectives of this study, a survey instrument was developed for mailing to Ohio subsurface drainage contractors. Several iterations of the instrument were developed prior to sending a draft instrument to several key people for review. Reviewers included Art Brate and Mike Monan of USDA-NRCS, Dale Arnold of Ohio Land Improvement Contractor's Association (OLICA), Kevin Elder of ODNR-DSWC, Fred Galehouse (drainage contractor) and Scott Ganz (drainage contractor). Comments by the reviewers were addressed in the final survey instrument.

The names and addresses used for the survey were obtained from three sources: 1) the Overholt Drainage Education and Research Program mailing list; 2) the Ohio Land Improvement Contractor's Association (OLICA) membership list; and 3) soil and water conservation districts (SWCDs) in many counties of Ohio. This produced a list of approximately 475 names and addresses. Although it was suspected that many of the names on the resulting list were not active subsurface drainage contractors, no systematic attempt was made to remove inactive contractors or uninterested parties from the list in order to provide the greatest opportunity for all active subsurface drainage contractors to participate in the survey; only those very obviously not active contractors, and duplicates were removed from the list, producing a final mailing list of 393 names.

A modified Dillman (1978) approach was used for this survey. A postcard announcing the upcoming survey was mailed to all names on the mailing list. A week later, the survey packet was mailed. The survey packet contained the survey instrument, a self-addressed and stamped return envelope for the survey instrument, and a postcard to be returned separately from the survey instrument. Participants were to use the return postcard to confirm that the survey instrument had been completed and returned, or to inform us that they were not an active subsurface drainage contractor. Those respondents returning postcards were removed from subsequent mailings. By using a return postcard separate from the survey instrument, identification was not required on the survey instrument, thus ensuring completely anonymous responses.

One week following the mailing of the survey instrument packet, a reminder postcard was mailed. Three weeks after the initial survey instrument mailing, a second survey packet was mailed to those who had not returned postcards. At seven weeks, a third and final survey packet was mailed to those on the list who had not previously responded.

RESULTS AND DISCUSSION

The 1998 Subsurface Drainage Survey instrument was mailed to 393 potential subsurface drainage contractors. We received a total of 185 return postcards (47%) and 107 completed questionnaires (27%). However, only 73 postcards indicated that a survey had been returned and 112 postcards indicated that the respondent did not install subsurface drain pipe. Since only 73 postcards were received indicating a returned questionnaire, but there were 107 questionnaires returned, perhaps as many as 34 people completed a questionnaire without returning the postcard. If true, the total response rate could have been nearly 56% (219 of 393) of the total mailing.

Since the survey responses were meant to be completely anonymous, it is difficult to reconcile the disparity between the 107 returned surveys and the 73 postcards indicating a returned survey. Two possible scenarios to explain this are: 1) some respondents returned both a completed survey and a return postcard indicating they did not install subsurface drain pipe, or 2) respondents completed a survey but did not return the postcard. There were 14 questionnaires returned by people or firms that did not install drain pipe during the survey period, which supports the first scenario. Presumably the second scenario explains the 20 additional returned questionnaires.

The initial motivation for doing the survey was to gather information in support of the Ohio Agricultural Water Management Guide. A major part of the guide focuses on using computer modeling to formulate drain depth and spacing recommendations for the more than 475 soils series mapped in Ohio. It was felt that a survey of subsurface drainage contractors could obtain the drain depths and spacing they actually use, and would provide insight on how well the modeling reflected installation practices. While the survey questionnaire focused on this issue, more general information was requested in an attempt to profile subsurface drainage contractors in terms of their equipment use, design practices, attitudes and educational needs.

Subsurface drainage contractor profile

It was expected that there would be a wide range in size of the firms responding. Some firms install drain pipe as their main business and have large crews, while others might be one person operations. A natural method of dividing the responses for analysis is between firms for which subsurface drain installation is their primary business and firms for which it is a sideline business. We found that 59 respondents considered subsurface drain installation their primary business, while 48 respondents did not. In this paper, we will call firms that consider subsurface drain pipe installation their primary business “mainline” firms, while those that do not consider subsurface drain pipe installation their main business will be called “sideline” firms.

The mainline and sideline firms show considerable differences in terms of length of time in business. On average, the mainline firms have been in business over 11 years more than the sideline firms, with an average of over 32 years in business. Over 90% (54 of 59) of the mainline firms responding have been in business for 11 years or more, and nearly 29% (17 of 59) have been in business over 41 years. One mainline firm reported being in business for 98 years. In comparison, over 29% (10 of 34) of the sideline firms that reported subsurface drain installation in 1995-1997 have been in business less than 10 years, and only 1 sideline firm has been in business over 41 years. These mainline firms in general have much experience with subsurface drainage.

There are some differences in the equipment used by the mainline firms compared to the sideline firms. The proportion of firms in each category using wheel machines to install drain pipe is about the same, but mainline firms are twice as likely to use chain trenchers (23.7% vs. 11.8%) and plows (52.5% vs. 26.5%) as the sideline firms. Chain trenchers and plows are more expensive to own and maintain, so they would require a high usage rate to be cost-effective, thus favoring usage by the mainline firms.

Another issue addressed in this survey was the contractors' interest in potential educational topics. Respondents were asked to rate each of 16 topics using a 5-point Likert-type scale. The various topics were ranked similarly by both categories of drainage firm. The effects of compaction on drainage and drain pipe quality (4.8 rating) were the two highest rated topics by the mainline firms, with adequate outlets and installation standards rated nearly as high (4.6 rating). Drainage economics and the rights of upstream landowners are the next highest rated topics.

Since this survey was related to the Ohio Agricultural Water Management Guide, which is meant to be a resource to drainage contractors, one section of the questionnaire asked about the resources contractors used in determining size, depth, spacing and other design considerations prior to installing a drainage system. A list of seven resources was provided, and respondents were asked to rate their usage of each of these resources on a 5-point Likert-type scale.

There was very little difference when the responses were stratified by mainline vs. sideline firms, so only the mainline firm summary is reported, as these firms are responsible for most drain pipe installation. Mainline firms were slightly less likely to use the soil survey, a hydraulic conductivity test, or a private consultant to help with the design of a system compared with sideline firms. Although hydraulic conductivity is one of the main criteria in the design of a drainage system, a hydraulic conductivity test is rarely conducted. This is probably because of the large number of samples needed to properly estimate the hydraulic conductivity (Schwab et al., 1982), because of inherent spatial variability in the soil, and variability introduced by farm management decisions.

Only a self-prepared elevation map of the site, and the contractor's experience were reported to be consistently used more than 25% of the time by a substantial percentage of the respondents. These two resources were used about 75% or more of the time by over 80% of the mainline contractors. Even a soil survey is not frequently used as 75% of the respondents reported using the soil survey 25% of the time or less. Apparently drainage system design is based almost exclusively on contractor experience and topography of the site, in spite of recognized variability in drainage system response among sites (Schwab et al., 1982).

Contractors often price jobs by the amount of pipe installed, thus the incentive is to maximize pipe installation, leaving little incentive to place much effort into the design of a system. Contractors only make money when the machine is working. For these reasons, we wanted to explore how receptive contractors would be to working with private consultants to provide better design information for themselves and to their clients.

The design phase was split into two components: 1) obtaining a topographic survey, and 2) completing the actual design. No details were provided regarding the design process. For instance, it was not made clear that a hydraulic conductivity test might be part of the design process. This deficiency should be addressed in future surveys.

A 5-point Likert-type scale was used to rate the respondents interest in using a consultant to obtain a topographic survey and a drainage system design. Overall, sideline firms were slightly more interested in using consultants to provide these services than were mainline firms. The overall interest was low for both groups. Only 7 of 58 mainline firms (12%) were interested or very interested in using a consultant for topographic surveys, while 8 of 34 sideline firms (23.5%) were interested or very interested. A slightly higher percentage of each group was interested or very interested in using a consultant for drainage system design: 9 of 58 (15.5%) of the mainline firms and 9 of 34 (27.2%) of the sideline firms.

The 15 mainline and sideline firms interested or very interested in hiring a topographic survey installed 4 145 km (13.6 million feet) of drain pipe over the three years of the survey, about 15%

of the total reported, and enough to systematically drain about 5 261 ha (13,000 acres). The 18 firms interested or very interested in having a consultant complete the system design installed 3 932 km (12.9 million feet) of drain pipe, about 14% of the total drain pipe installation reported. Only 12 firms responded to both questions.

We next asked the respondents about the value of these services to the contractor or his client. The potential value of these services can be pretty high. Among those firms that provided an estimate of value for these services, the average amount firms estimated they or their clients would be willing to pay for a topographic services ranged from $10.63 to $13.84 per ha ($4.30 to $5.60 per ac), with a high value of $49.42 per ha ($20.00 per ac). For system design, estimates ranged from $8.90 to 16.56 per ha ($3.60 to $6.70 per ac). One firm estimated that clients would be willing to pay as much as $61.78 per ha ($25.00 per ac) for a drainage system design.

A higher number of mainline firms provided value information than did the sideline firms. The mainline firms responding to this question seemed to place more value on design assistance than did the sideline firms, and on average were willing to pay nearly twice as much ($6.70 vs. $3.60) per acre for design assistance.

While this survey does provide some insights into subsurface drainage contractor's activities and attitudes, some of the topics could have been explored further. An open-ended question about each firms' design process would be appropriate. This question could investigate how contractors design projects and their needs for additional tools or information. Additional topics that would be useful would be: cost of installation, size range of jobs, use of drain spacing equations, and the use of computer software to design a drainage system.

<u>Subsurface drainage installation activity in Ohio</u>

Firms whose main business is drain pipe installation installed about 89% of the total reported in this survey. Overall, a firm installing drain pipe as their main business installed an average of 4.6 times as much drain pipe as did a firm installing drain pipe as a sideline.

The trend indicated increasing amounts of drain pipe installation in each year of the survey, especially for mainline firms. While some of this may be because of the fact that more firms reported in 1997 compared with 1995, it may also be because of improved weather-related installation conditions, or increased demand. The same mainline firm reported the maximum amount of drain pipe installation in each year of any firm in the survey. This firm increased its productivity by about 152 400 m (500,000 ft) per year during the three years of the survey. There was no information provided in the survey to learn why this firm's productivity increased by this amount. Nor was there any attempt made to estimate demand in this survey. Questions relating to changing productivity and demand may be appropriate in a future survey.

<u>Water table management practices</u>

Respondents were asked to indicate if they had installed either new or retrofitted controlled drainage (CD) systems during the years 1995-1997. Only 8 contractors reported the installation of 13 new CD systems, and 5 reported the retrofitting of 8 systems. Ten of the new CD systems affected a total of 117 ha (290 ac) of land, and 7 of the retrofitted systems affected 139 ha (343 ac). Only three new CD systems controlling 10.1 ha (25 ac) were known to have some type of waste products applied to the land affected. Five contractors reported on the management of systems they had installed, and indicated that 70% (7 of 10) of the new CD systems were being managed successfully. The four contractors reporting on the management of retrofitted CD systems reported more successfully managed systems than they had installed, making these answers suspect.

Respondents were also asked about the installation of subirrigation (SI). Again, not all contractors who reported the installation of these systems provided the additional data requested. Five contractors reported the installation of 18 SI systems, but one contractor accounted for 11 of these.

Total area affected by these 18 systems was 186 ha (460 ac), an average of 10.3 ha (25.5 ac) per system. Seven contractors reported retrofitting 8 systems for subirrigation, affecting 177 ha (438 ac), an average of 22 ha (55 ac) per system. The number of control structures was underreported, with fewer control structures than systems. The contractors may not have understood this question.

An adequate water supply is critical for an SI system. A source capable of producing 47.2 l pm per ha (5 gpm per acre) is required to meet maximum ET demands. The most common water source for SI systems was a pond. Fourteen of the 18 new SI systems (78%) and 5 of the retrofitted SI systems (63%) used a new pond for the water supply, while existing ponds were a source of water for two each of the new and retrofitted SI systems. Streams were a source of water for two new and three retrofitted SI systems. Existing wells were a source of water for one new and three retrofitted SI systems. No new wells were constructed to provide water to SI systems. One of the new SI systems and three of the retrofitted SI systems had multiple sources of water. Two of the new SI systems (11%) and two of the retrofitted SI systems (25%) included new wetlands as a component of the system.

Four contractors reported that 86% (6 of 7) of the new SI systems installed were being managed successfully. However, the contractor that constructed 11 systems reported he did not know if they were being managed successfully.

Controlled drainage systems and subirrigation systems accounted for a very small fraction of subsurface drain pipe installed by the respondents from 1995 through 1997. Although these systems have the potential to reduce the adverse environmental effects of subsurface drainage (Skaggs et al., 1994), they do not seem to be frequently installed in Ohio. One respondent mentioned that "*We had a lot of interest in sub-irrigation in the 1980s. I haven't even heard it mentioned in the last five years*." The management requirements, increased design effort needed for a successful system, site constraints including topography and water supply needs, and increased costs likely contribute to low interest in these systems. Brown et al. (1998) are investigating the integration of subirrigation with constructed wetlands and water supply reservoirs in Northwest Ohio, and these studies may lead to increased interest in subirrigation in Ohio. More detailed studies will be necessary to document the extent of subirrigation and controlled drainage systems in Ohio.

<u>Drain depth and spacing by soil series</u>

One of the main goals of the survey was to determine the depth and spacing values drainage contractors use to install drain pipe in various soil series. To assess the depth and spacing values used by contractors when installing drain pipe, respondents were asked to provide estimates of typical, minimum, and maximum depth in inches and spacing in feet used for the installation of lateral drains by soil series. A list of 28 soil series was provided, with the option for the respondents to add other soil names. This list consisted of the 28 soils of greatest area in Ohio having a high water table sometime during the year, derived from the State Soil Survey Database.

Responses were obtained for 60 soil series. Two respondents indicated they did not know the soil series, while nine others provided textural or descriptive responses such as black, clay, sand, muck, or gravel, to the question. A number of contractors apparently do not consider the soil series in the design of a drainage system. Seven respondents indicated that they used the same depth and spacing values for all soils.

Ninety contractors reported depth values for multiple soils. Fifty-seven of 90 (63%) provided identical values for typical, minimum and maximum installed depth for each of the soils they listed. In some cases the soils listed have very similar characteristics (e.g., Bennington and Blount (USDA-SCS, 1994)), but in other cases the soils listed have characteristics different enough to warrant different installation depths (e.g., Blount and Haskins (USDA-SCS, 1994)). However, drain depth is often limited by outlet conditions and not soil characteristics, and the values provided may reflect this constraint more than the variation in characteristics among the soils. No attempt was made in this survey to find out if the soil characteristics, the outlet conditions, or other factors controlled the installation depth used.

There were 269 soil series/contractor entries provided for typical depth, 270 for minimum installation depth, and 264 for maximum installation depth. A typical installation depth of 79-91 cm (31-36 in) was reported by 58% (156 of 269) of the respondents, while another 26% (70 of 269) reported a typical installation depth between 64 cm (25 in) and 76 cm (30 in). Minimum installation depth responses fell mainly into two ranges: 48-61 cm (19-24 in) (47%) and 64-76 cm (25-30 in) (44%). Maximum installation depth varied more, with the largest number of responses in the 109-122 cm (43-48 in) range (32%), followed by 94-107 (37-42 in) (27%) and 79-91 cm (31-36 in) (21%).

For the named soil series, there were 270 soil series/contractor entries provided for typical spacing, 236 for minimum spacing, and 228 for maximum spacing. As for the installation depth responses, many of the contractors do not appear to change spacing for different soils. Thirty-three of 90 contractors (37%) indicated the same typical installation spacing for the soil series they reported, while 28 of 90 (31%) indicated the same typical, minimum and maximum installation spacing.

The frequency that various spacing values used for minimum, typical and maximum drain spacings were reported by the respondents. The greatest number of responses indicated a typical spacing of 12.2 m (40 ft) (35%), with the second greatest number of contractors using a spacing of 15.2 m (50 ft) (20%). Responses for minimum installation spacing show less variability, likely because of the increasing cost of installing closely spaced drains. Contractors reported 7.6 m (25 ft) (24%) and 9.1 m (30 ft) (25%) nearly equally, with 19% indicating a minimum spacing of 12.2 m (40 ft).

The greatest number of responses for the maximum spacing were for a spacing of 15.2 m (50 ft) (40%), with the 12.2 m (40 ft) spacing selected by 19% of the respondents. Values used for maximum spacing varied more than minimum or typical spacing, ranging from 7.6 to 30.5 m (25 to 100 ft).

<u>Evaluation of individual soils for depth and spacing</u>

A major objective of this study was to compare the depth and spacing used by contractors with depth and spacing values computed using the Hooghoudt equation using the permeability values found in the Soil Interpretation Records (SIR) contained in the State Soil Survey Database for Ohio. Lucas (1982) compared the field performance of subsurface drainage systems in 14 Midwest soils with the Hooghoudt equation and reported that reasonable values of drain spacing were obtainable using permeability values contained in the NRCS Soil Interpretation Records.

Of the 60 soil series with depth and spacing data, there were 8 soil series with data provided by 10 or more respondents that were also in the group of benchmark soils for which drain spacing evaluations had been completed using the Hooghoudt equation (Atherton, 1999). For each of these soils, both depth and spacing responses were examined. Some respondents did not provide individual values for each of the items (typical, minimum, and maximum depth and spacing) requested. For example, there were 27 respondents that provided some information for the Hoytville series. However, only 20 provided complete information for depth and only 19 provided complete information on spacing. Three respondents wrote in ranges for the typical depth, while four did not provide information for at least one item (typical, minimum, or maximum depth). Only those responses that provided complete data for either drain depth or drain spacing were selected for further analysis.

On average, subsurface drains are installed between 76.2 cm (30 in) and 91 cm (36 in) deep on these soils, although the typical installation depth reported ranged from 61 cm (24 in) to 114 cm

(45 in). These values correspond quite well with the average installation depth for all soils reported. However, respondents were not asked to specify whether depth was constrained by soil attributes or by outlet conditions, so it is not certain that the reported depths were constrained only by soil conditions.

A soil attribute that would influence drain depth is the depth to a restrictive layer. The results were examined to determine if the contractors were influenced by the depth to restrictive layer reported by SIR data. For example, data for the Crosby soil series shows a layer beginning at about 71 cm (28 in) deep that could be a restrictive layer. However, respondents indicate that drains in the Crosby are typically installed at 91 cm (36 in), 20 cm (8 in) deeper than the typical restrictive layer reported in the SIR. While this could indicate a lack of consideration for the restrictive layer, it could also reflect the natural variance of the depth to this layer. Only a site-by-site determination could resolve this issue. On the other hand, the Mermill soil series has a restrictive layer at about 86 cm (34 in) deep, nearly the same depth as the typical drain installation.

The other soils do not have a soil layer that acts as a restrictive layer, based on permeability data in the SIR. However, some soils have very low permeability. For example, data in the Paulding SIR show this soil to have extremely low permeability. Using the SIR values in the Hooghoudt equation results in a calculated drain spacing of less than 3 m (10 ft), even using the high permeability value. A drainage system with such a narrow spacing would be very expensive to install.

Typical minimum and maximum spacing reported for these 8 soils were compared with the spacing calculated using the Hooghoudt equation based on a steady-state water table depth of 30 cm (12 in)and a drain depth of 90 cm (35 in) (Atherton, 1999). For all soils, the typical installation spacing reported is usually greater than that calculated by the Hooghoudt equation. Only for Brookston (1 instance) and Mermill (2 instances) is a typical installation spacing reported in the range calculated by Hooghoudt. Except for the Crosby and the Paulding soils, a minimum spacing is reported in the Hooghoudt range for all soils. Information on the effectiveness of the installed spacings for various soils is lacking. It has been suggested that fractures in the glacial till, or other causes of increased flow may allow wider spacings to perform satisfactorily in the field. It may also be that producers are making a tradeoff between performance and cost of installation. It would take a detailed study to resolve some of these issues.

The range of typical spacing is quite wide for Brookston (9.1 - 20.1 m) (30 – 66 ft) and Crosby (12.2 - 21.3 m) (40 – 70 ft) compared with the other soils, which all have a range 15 ft wide. Unfortunately, this study did not request additional information that would help to analyze the variability in responses.

Schwab et al. (1982) reported on a field evaluation of drainage systems on several soils in Ohio, including two sites with Paulding soils. Their objective was to determine pipe drain spacing recommendations for these soils. On the first Paulding site, the water table depth at mid-spacing was shallower than 30 cm after 24 hours, so an effective drain spacing could not be calculated. However, on the second site the water table was below 30 cm deep after 24 hours, and a drain spacing of 5.7 m (19 ft) was calculated. Schwab et al. (1982) indicated that the producer's soil management was quite different at these two sites, and questioned whether soil type should be used as the only basis for drain spacing calculations.

In addition to the Paulding soil series, Schwab et al. (1982) calculated drain spacings for Hoytville (11.8 m, 39 ft) and Nappanee (7.7 m, 25 ft) which are higher than spacings calculated from the Hooghoudt equation using the high permeability values for these soils. However, the Schwab et al. (1992) calculations are based on an unsteady-state equation, and thus the results obtained may not be strictly comparable to the steady-state Hooghoudt equation.

While this study provides information on how drainage contractor practices compare with the Hooghoudt equation calculations, it provides no information regarding the effectiveness of the systems installed. It should not be assumed that all systems are equally effective. Each site is likely to have different characteristics that would allow different drain spacings, even within the same soil series, as shown by Schwab et al. (1982) in the above example.

It would be very helpful to have additional information for the analysis of these data. An open-ended question about the contractors' selection of drain spacing and depth might provide useful information. Contractors could be asked whether drain depth was constrained mostly by outlet conditions or by soil characteristics. They could also be asked if the installation spacing was affected by the depth of installation used. To be most useful, these questions should be related to specific soils. Soil management practices appear to affect a field's drainage characteristics, and might influence the spacing selected by contractors.

CONCLUSION

A mail survey of drainage contractors was conducted in early 1998. Of 393 survey packets mailed, 107 completed questionnaires were returned. For the survey period, 1995 through 1997, 59 mainline and 34 sideline contractors installed nearly 90 million feet of drain pipe, with the mainline contractors responsible for 89% of the total. The installation of drain pipe increased in each year of the survey. Very few controlled drainage or subirrigation systems were installed during the survey period.

Mainline contractors were more likely to use drain plows than sideline contractors.

Drainage contractors were queried about several possible educational topics relevant to the drainage industry. The effects of compaction on drainage, drain pipe quality, adequate outlets and installation standards were the highest rated topics by both mainline and sideline firms.

Drainage contractors make little use of soil surveys or the Ohio Drainage Guide when designing a system, relying primarily on experience and a self-generated topographic map. Almost none use a hydraulic conductivity test. Only 12% of mainline firms and 23.5% of sideline firms were interested or very interested in using a consultant for topographic surveys. A slightly higher percentage of each group was interested or very interested in using a consultant for drainage system design.

Drain pipe is installed at depths ranging from 46 to 183 cm (18 to 72 in), but is typically installed from 76 to 91 cm (30 to 36 in) deep for many soil series. Drain spacing values reported ranged from 5.5 to 30.5 m (18 to 100 ft). Many drainage contractors reported the same typical, minimum and maximum depth and spacing values for multiple soil series, suggesting that drains are often installed without much regard for differences in soil types.

In general, drains are typically installed at spacings greater than that calculated using the Hooghoudt equation with permeability data from the SIR records. Only for those soils for which the Hooghoudt calculation results in a spacing approaching 12.2 m (40 ft) is there much overlap with contractor practices. This may be because of the increased cost incurred when installing drain pipe at narrower spacing. Many contractors may consider recommendations based on the Hooghoudt equation to be overly conservative or impractical.

Recommendations for future work

While this survey does provide some insights into subsurface drainage contractor's activities and attitudes, some of the topics could have been explored further. An open-ended question about each firms' design process would be appropriate. This question could investigate how contractors design projects and their needs for additional tools or information. Contractors could be asked whether drain depth was constrained mostly by outlet conditions or by soil characteristics. They could also be asked if the installation spacing was affected by the depth of installation used. To be most useful, these questions should be related to specific soils and soil management practices.

Additional data that would be useful include: cost of installation, size range of jobs, use of drain spacing equations, and the use of computer software to design a drainage system.

The trend indicated increasing amounts of drain pipe installation in each year of the survey, especially for mainline firms. Questions relating to changing productivity and demand may be appropriate in the next survey.

Last, a study on the effectiveness of drainage systems installed at various depths and spacings would be useful. We know there is a wide range of typical installation spacings used by contractors, but we do not know how the effectiveness of these systems might vary.

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